Engaging Students in Atmospheric Science Field Campaigns

Greg McFarquhar
University of Illinois

June 10, 2009.


TRUCK WASH
03.08.2009 13:55


COMMERCE
06/02/2003 10:08:13


UA Huntsville
MAX
Mobile Alabama X-band
Dual Polarization Radar
BARON
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The Right Technology.
Right Away.
NEC
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Microphysical and Thermodynamic Structure and Evolution of the Trailing Stratiform Regions of Mesoscale Convective Systems during BAMEX. Part I: Observations

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ABSTRACT

This study used airborne and ground-based radar and optical array probe data from the spiral descent flight patterns and horizontal flight legs of the NOAA P-3 aircraft in the trailing stratiform regions (TSRs) of mesoscale convective systems (MCSs) observed during the Bow Echo and Mesoscale Convective Vortex Experiment (BAMEX) to characterize microphysical and thermodynamic variations within the TSRs in the context of the following features: the transition zone, the notch region, the enhanced stratiform rain region, the rear anvil region, the front-to-rear flow, the rear-to-front flow, and the rear inflow jet axis. One spiral from the notch region, nine from the enhanced stratiform rain region, and two from the rear anvil region were analyzed along with numerous horizontal flight legs that traversed these zones. The spiral performed in the notch region on 29 June occurred early in the MCS life cycle and exhibited subsaturated conditions throughout its depth. The nine spirals performed within the enhanced stratiform rain region exhibited saturated conditions with respect to ice above and within the melting layer and subsaturated conditions below the melting layer. Spirals performed in the rear anvil region showed saturation until the base of the anvil, near −1°C, and subsaturation below. These data, together with analyses of total number concentration and the slope to gamma fits to size distributions, revealed that sublimation above the melting layer occurs early in the MCS life cycle but then reduces in importance as the environment behind the convective line is moistened from the top down. Evaporation below the melting layer was insufficient to attain saturation below the melting layer at any time or location within the MCS TSRs. Relative humidity was found to have a strong correlation to the component of wind parallel to the storm motion, especially within air flowing from front to rear.

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Marcia Estrem
Joe Grim
Justin Hampton
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Andrew Rossenow
Junshik Um
Hee-Jung Yang
Henian Zhang

Outline

- Observations
  - Why we use, and why students needed
- Types of observations
  - In-situ, remote sensing, soundings
- Role of students
  - Duties in the field; after the project
- Unique opportunities
  - RICO field campaign; PLOWS
  - Data availability

Atmospheric Science is an Experimental Science

- ***Although models, theoretical studies and laboratory work play a major role in the atmospheric sciences, ultimately new theories and model performance can only be tested through observations of the state of the atmosphere***

Atmospheric Science is an Experimental Science

- *Although models, theoretical studies and laboratory work play a major role in the atmospheric sciences, ultimately new theories and model performance can only be tested through observations of the state of the atmosphere*

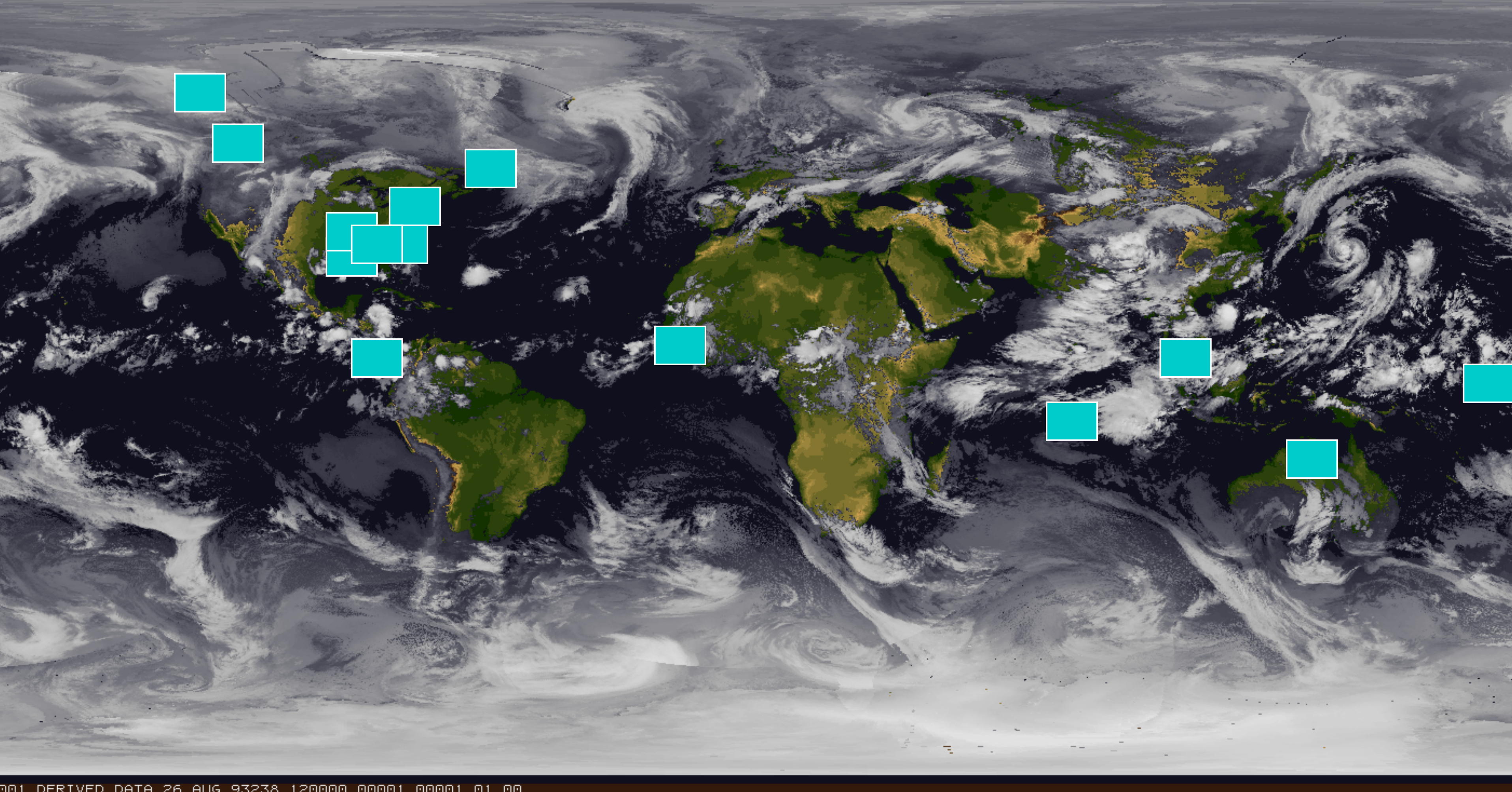
- **It is important that students play an integral role in these experiments not only to train the next generation of scientists, but also because of the unique thoughts & insights they provide**

A Personal Journey

- *My participation in field experiments as a graduate student and postdoctoral associate was a good part of what inspired me to continue in atmospheric science*
  - **Malaysian Rain studies 1990**
  - **Central Equatorial Pacific Experiment 1993**

Field Campaigns at Illinois

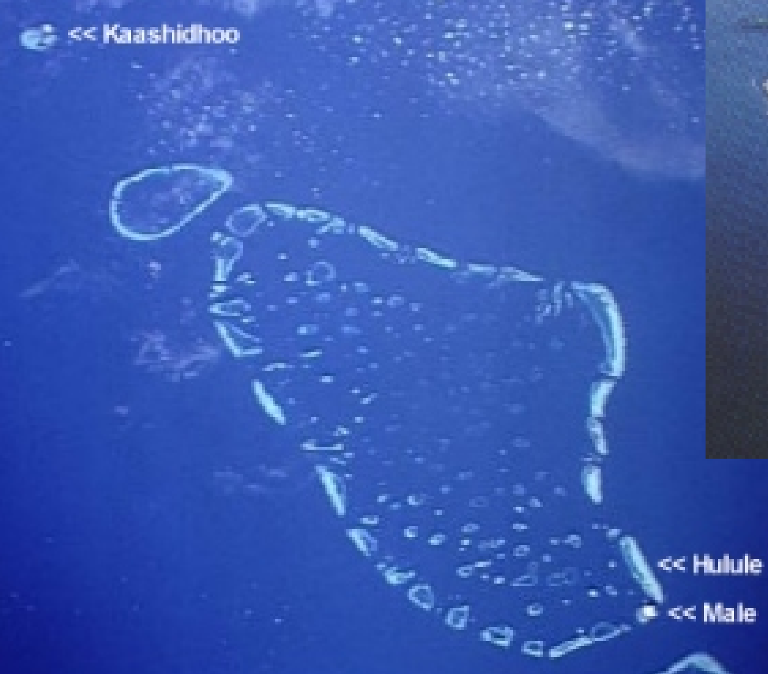
- ***One of the most fundamental and complex problems in weather research today is our poor understanding of the basic properties of clouds and our inability to determine quantitatively the many effects cloud processes have on weather***
- **Observations & multi-scale models must be used in combination to ultimately improve the representation of clouds in weather models**
- **This has been focus of many field campaigns at Illinois**



Cloud properties vary depending upon formation mechanism, height and geographic location

Projects have sampled clouds in a variety of locations


Thriving metropolis of Oliktok Point



Remote Islands of the Maldives

Costa Rica

Darwin, Australia

Cape Verde Islands

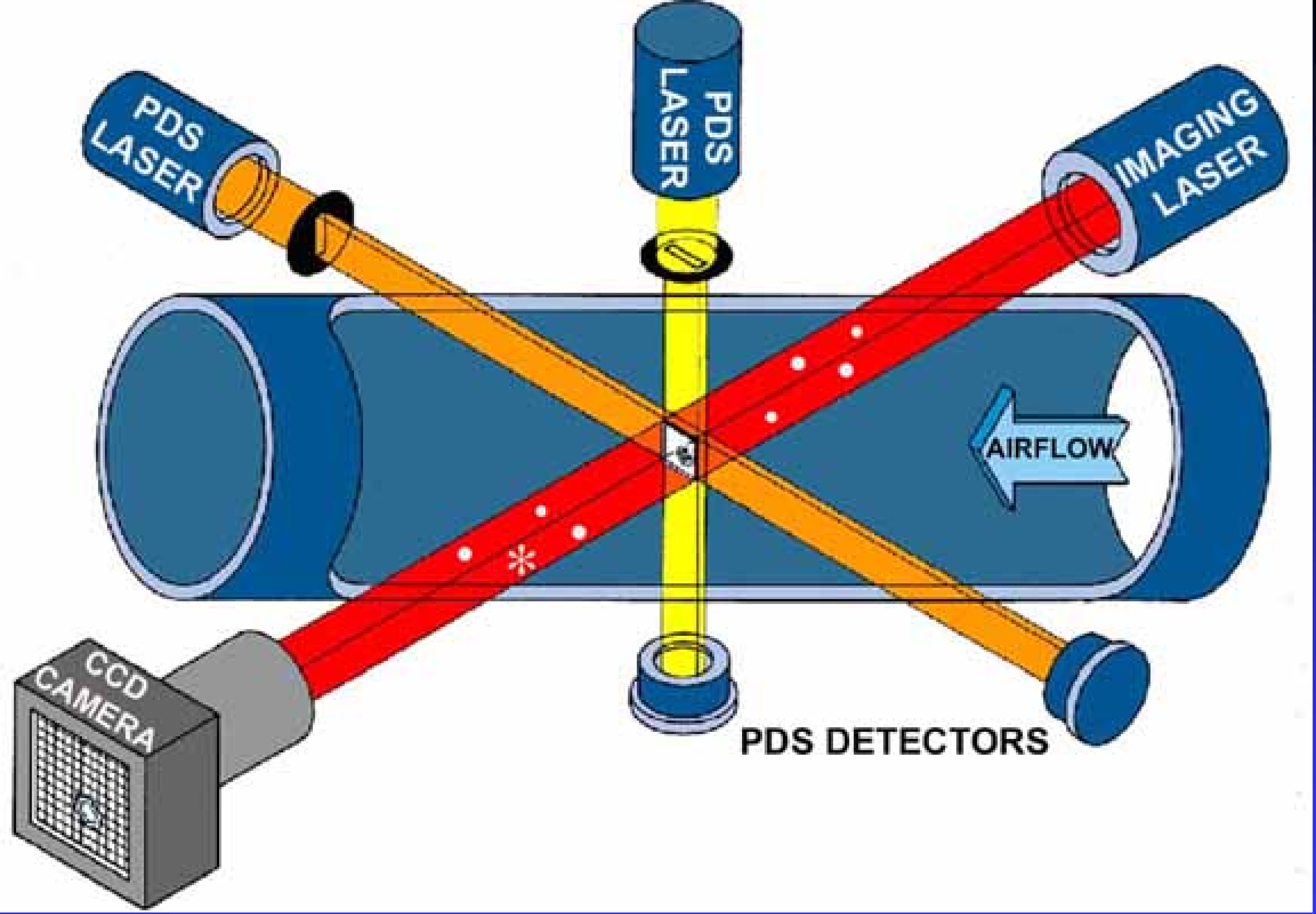
McFarquhar Group Projects 2001-08

Project	When	Where	What
CAMEX	Aug-Sep. 2001	Jacksonville, FL	QPFs for hurricanes
BAMEX	June-July 2003	St. Louis, MO	Bow echoes & mesoscale convective vortices
M-PACE	Sep.-Oct. 2004	Prudhoe Bay, AK	Arctic mixed-phase clouds
TCSP	June-July 2005	San Jose, Costa Rica	Hurricane Genesis
TWP-ICE	Jan.- Feb. 2006	Darwin, Australia	Tropical Cirrus & Radiation
GoMACCS	Aug. – Sep. 2006	Houston, TX	Impacts of aerosols on clouds
NAMMA	Aug. – Sep. 2006	Cape Verde Islands, Africa	Influence of aerosols on hurricane genesis
CLASIC	June 2007	Ponca City, OK	Cloud – land surface interactions
ISDAC	April 2008	Barrow, AK	Aerosol Impacts on Arctic Clouds

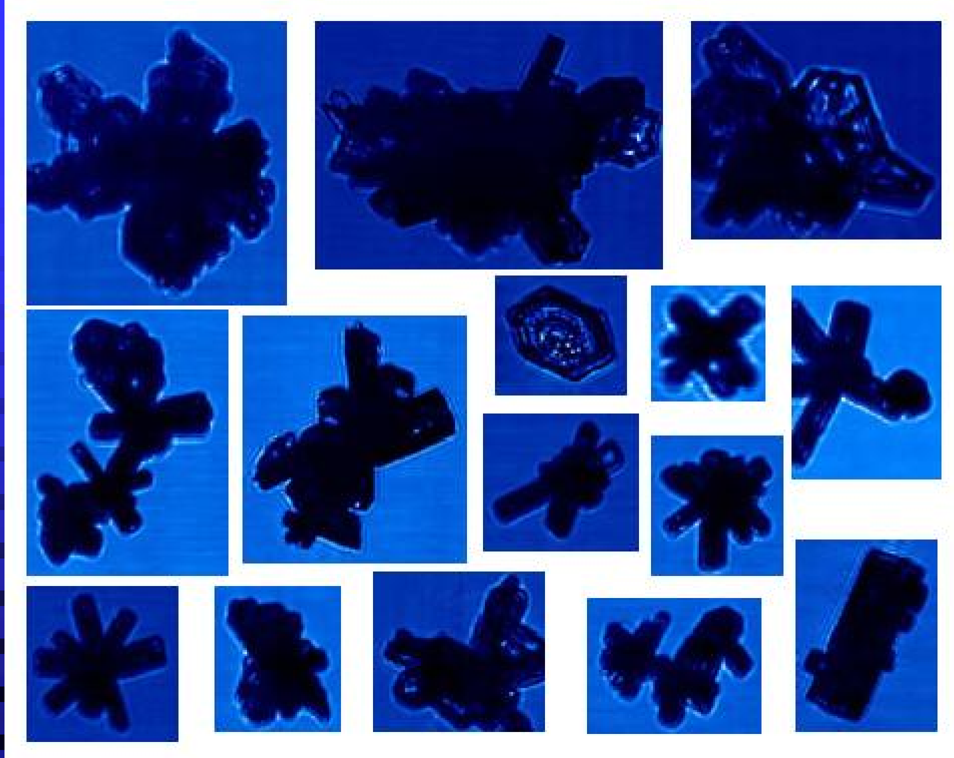
McFarquhar Ongoing Projects 2009

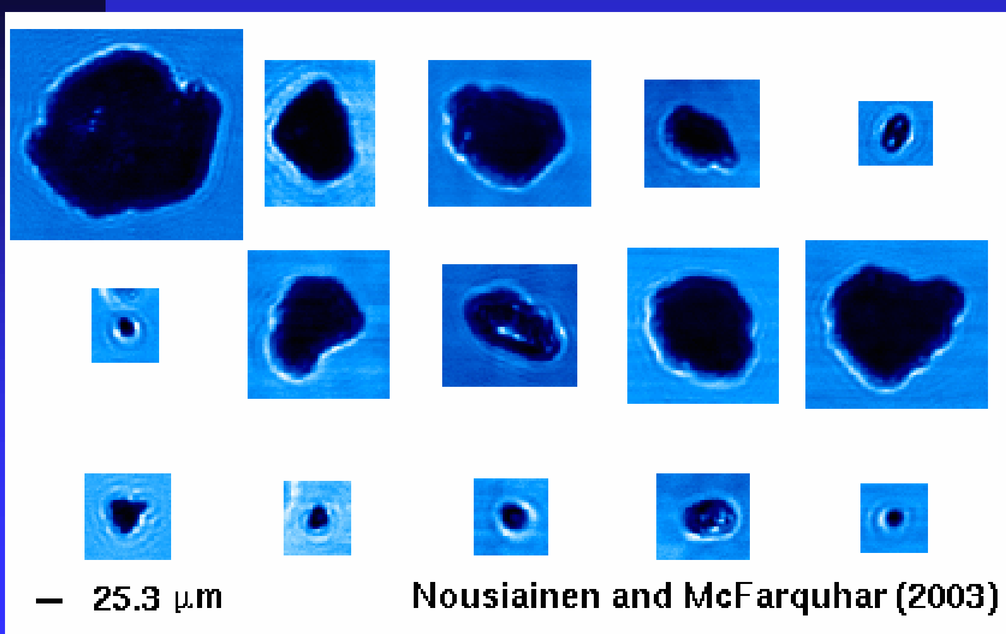
Project	When	Where	What
RACORO	**Jan. -June 2009**	**Guthrie, OK**	**Routine observations of low-liquid water clouds**
SPARTIC US	**Oct. 2009 to June 2010**	**Ponca City, OK**	**Routine observations of mid-latitude cirrus**
PLOWS	**Jan. to Feb. 2009 Oct. to Dec. 2009 Jan. to Mar. 2010**	**Champaign, IL Peoria, IL**	**Snowbands in winter time cyclones**

Observations: Use Aircraft



- Laser probes used to image sizes/shapes of particles



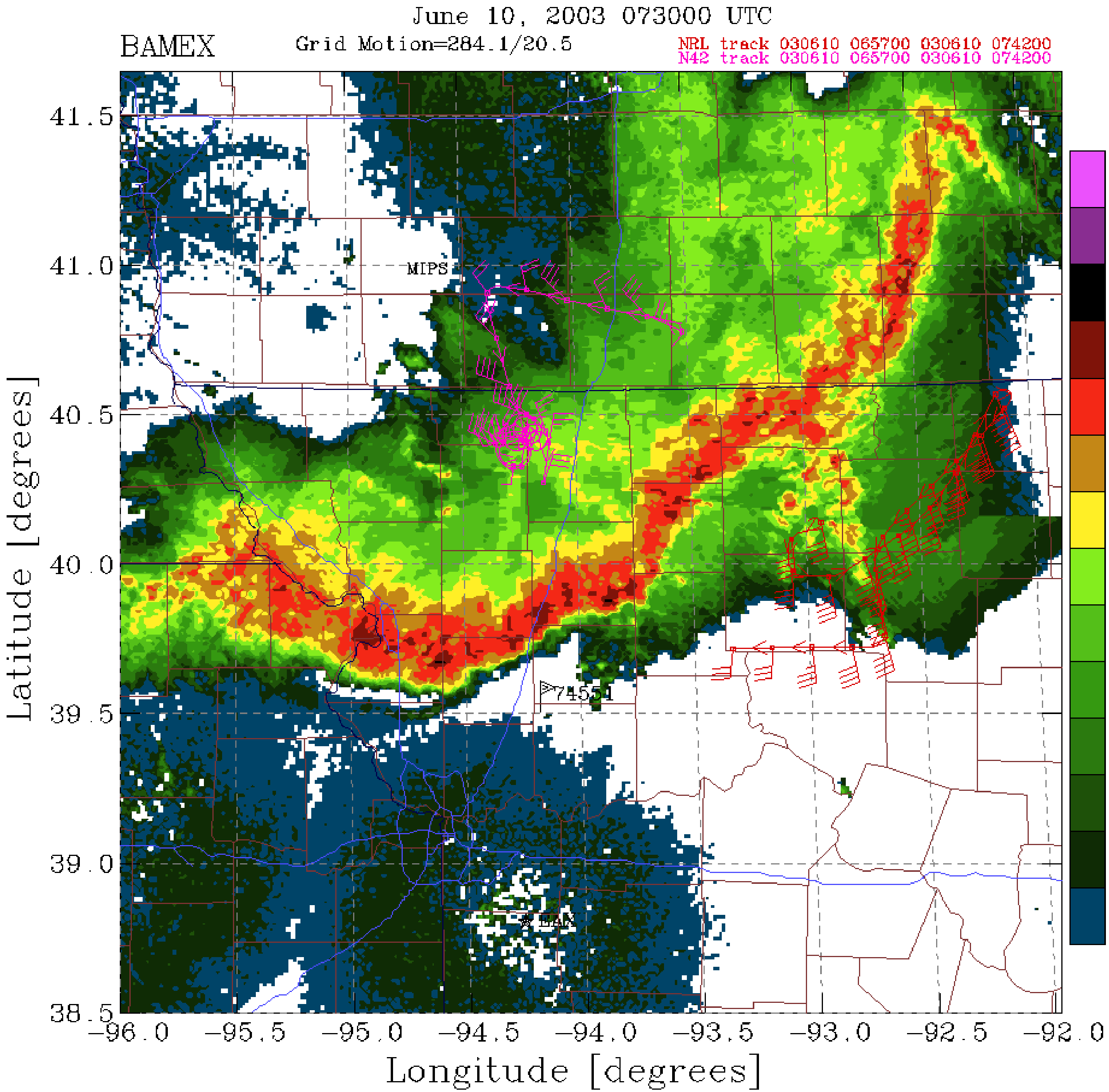


Aircraft probe observations of clouds can give us pretty pictures!

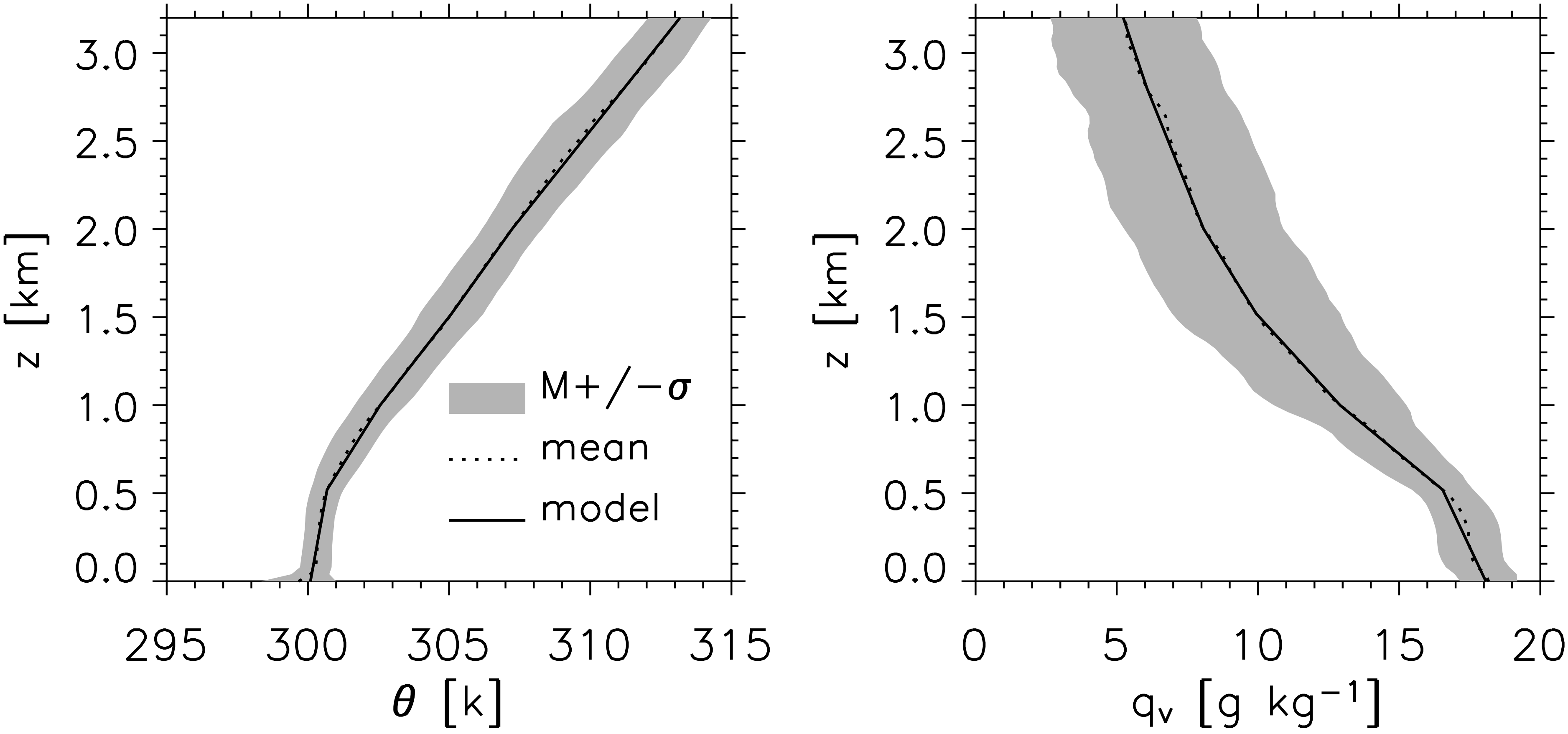
But, how do we go from pretty pictures to something that helps tell us how clouds affect climate & weather?

How do they help us represent clouds in models?

Observations: Use Ground Sensors


June 10, 2003 073000 UTC
BAMEX
Grid Motion=284.1/20.5
NRL track 030610 065700 030610 074200
N42 track 030610 065700 030610 074200
MIPS
Latitude [degrees]
Longitude [degrees]
41.5
41.0
40.5
40.0
39.5
39.0
38.5
−96.0
−95.5
−95.0
−94.5
−94.0
−93.5
−93.0
−92.5
−92.0
70
65
60
55
50
45
40
35
30
25
20
15
10

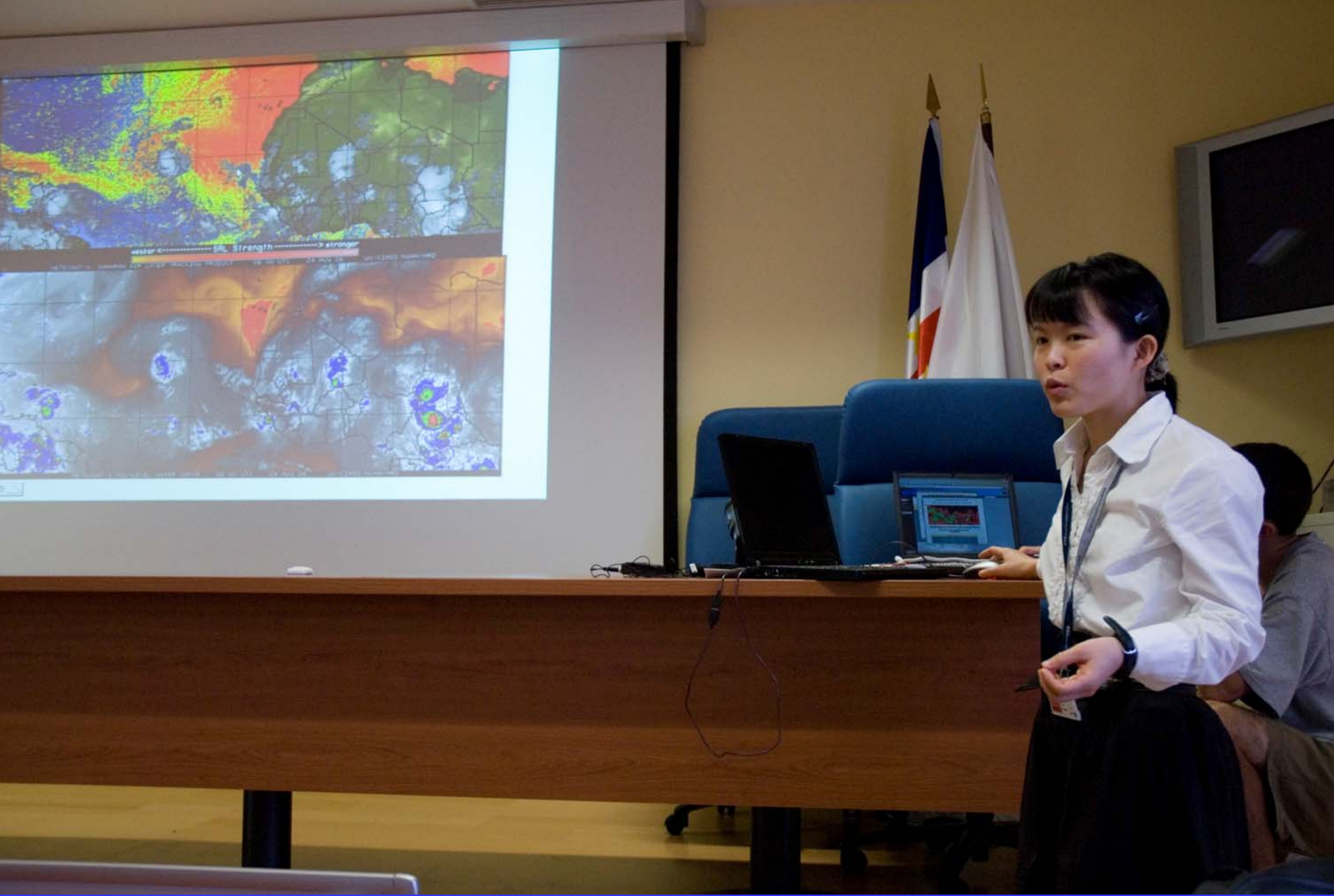
Observations: Radiosondes



3.0
2.5
2.0
1.5
1.0
0.5
0.0
z [km]
M+/−σ
mean
model
295
300
305
310
315
θ [k]
0
5
10
15
20
qv [g kg−1]

Student Roles

- **Weather Forecaster**


SAL Strength
stronger

Student Roles

- Weather Forecaster
- Monitoring Probes on Aircraft


06/02/2003 11:31:50

Student Roles

- Weather Forecaster
- Monitoring Probes on Aircraft
- Releasing Radiosondes

Student Roles

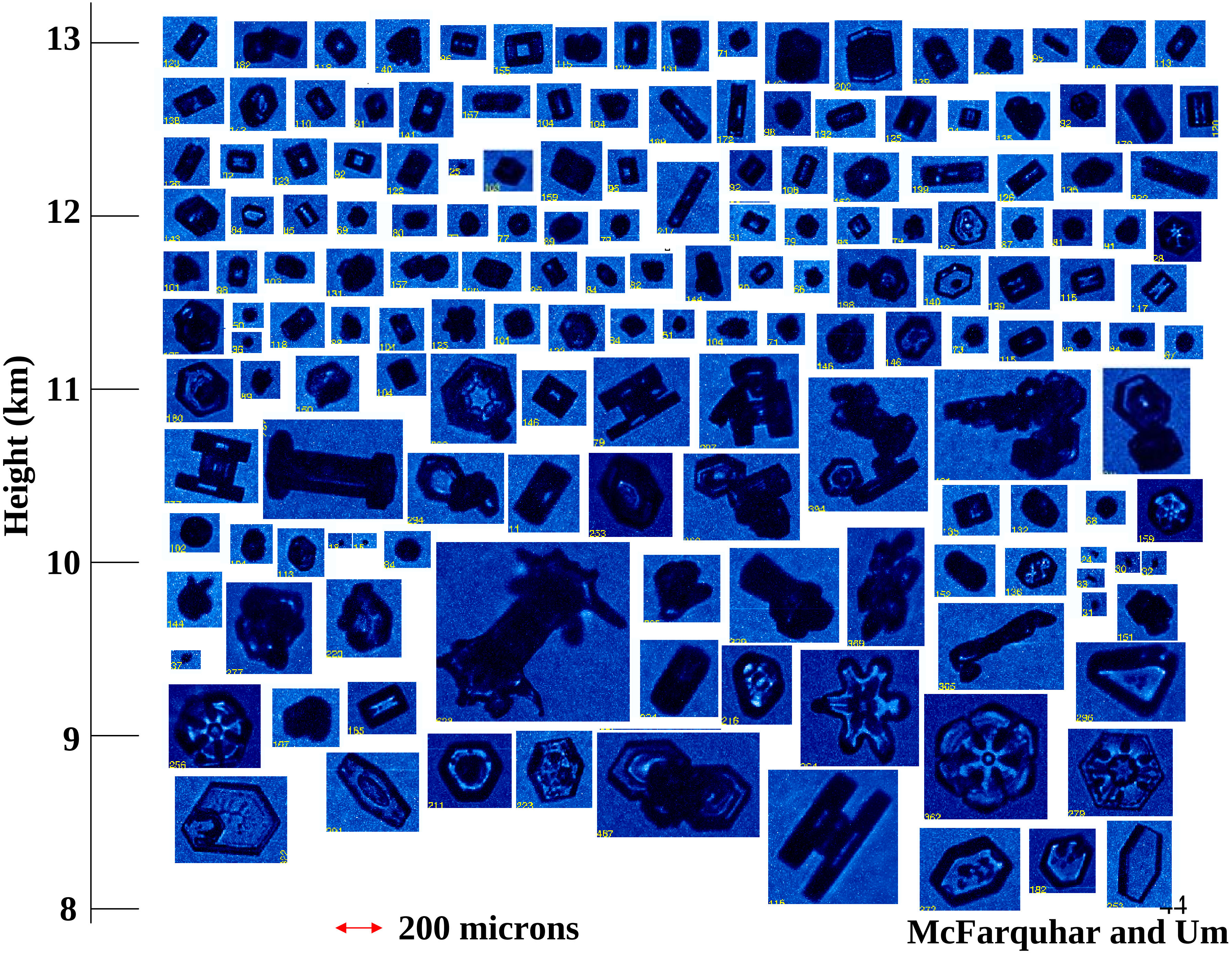
- Weather Forecaster
- Monitoring Probes on Aircraft
- Releasing Radiosondes
- Participating as part of Scientific Mission Planning as part of team


ARM-UAV
PROTEUS

UND Citation

Student Roles

- Weather Forecaster
- Monitoring Probes on Aircraft
- Releasing Radiosondes
- Participating as part of Scientific Mission Planning as part of team
- In field quality control/data analysis



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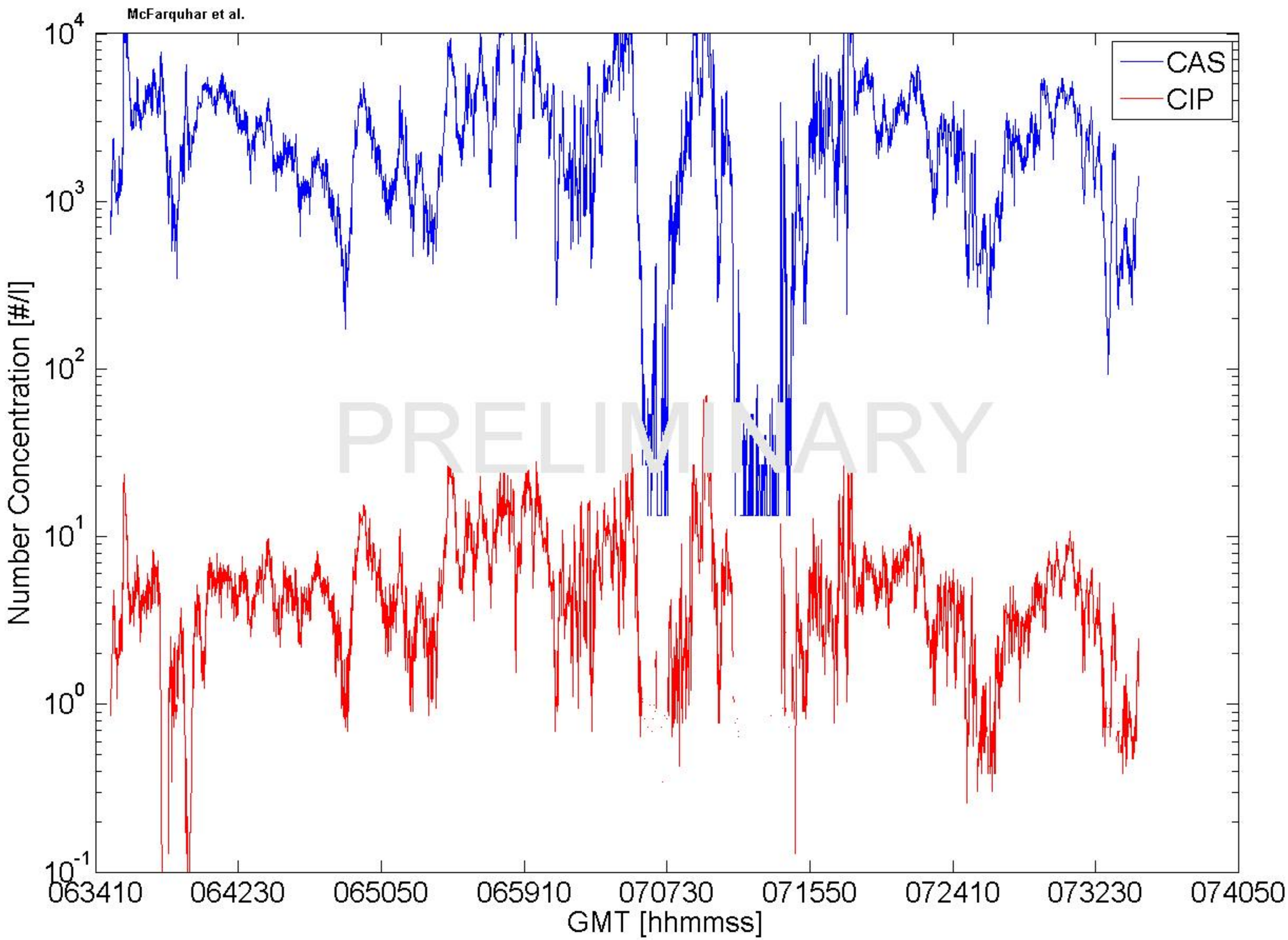
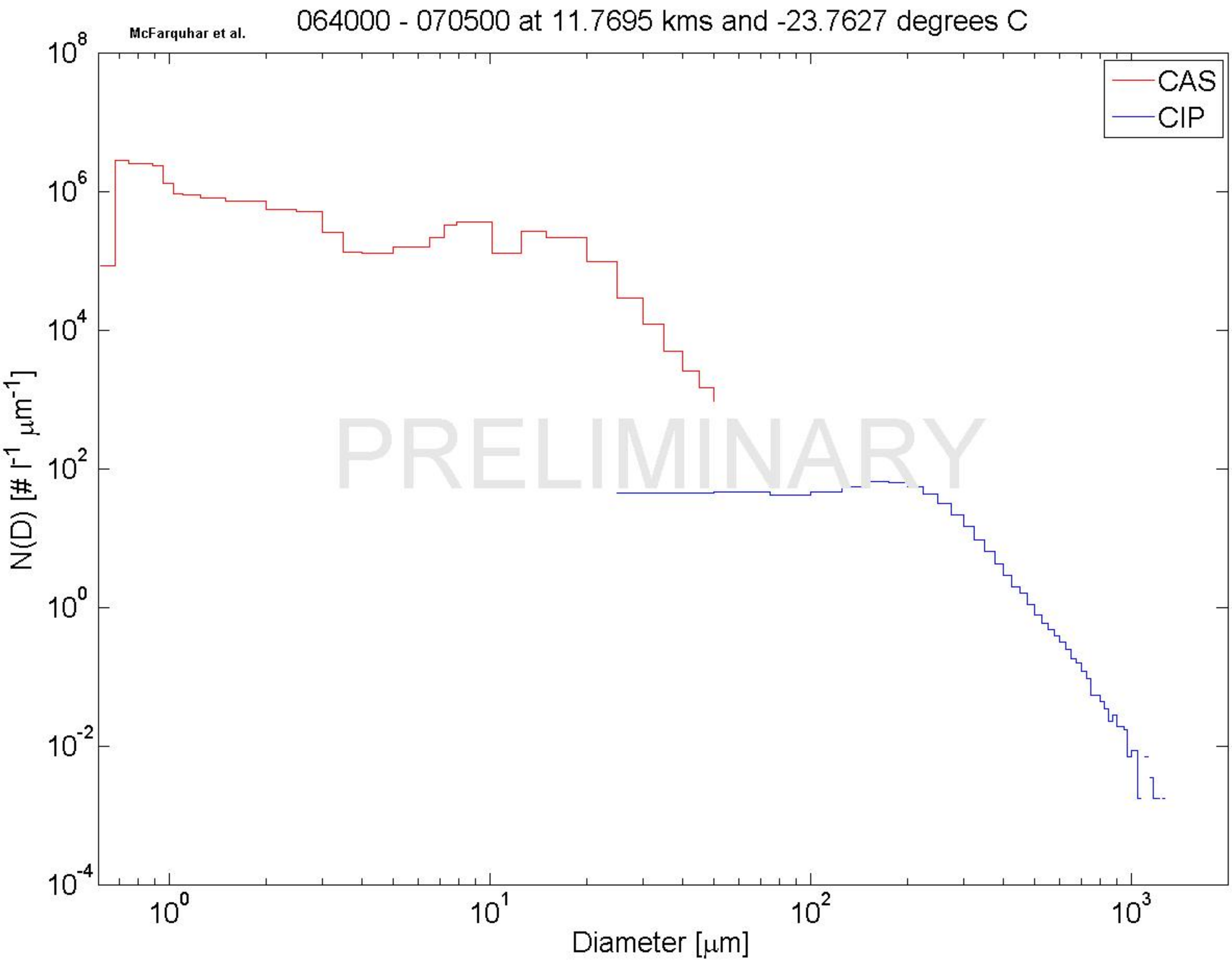

McFarquhar et al.
Number Concentration [#/l]
GMT [hhmmss]
CAS
CIP
PRELIMINARY
10^4
10^3
10^2
10^1
10^0
10^{-1}
063410
064230
065050
065910
070730
071550
072410
073230
074050


064000 - 070500 at 11.7695 kms and -23.7627 degrees C
McFarquhar et al.
CAS
CIP
PRELIMINARY
N(D) [# l^{-1} μm^{-1}]
Diameter [μm]
10^8
10^6
10^4
10^2
10^0
10^{-2}
10^{-4}
10^0
10^1
10^2
10^3

Student Roles

- Weather Forecaster
- Monitoring Probes on Aircraft
- Releasing Radiosondes
- Participating as part of Scientific Mission Planning as part of team
- In field quality control/data analysis
- After project science investigation

Do Aircraft Probes give absolute truth?

There are uncertainties in interpretation of aircraft data, just like there are uncertainties in remote sensors or model parameterization schemes.

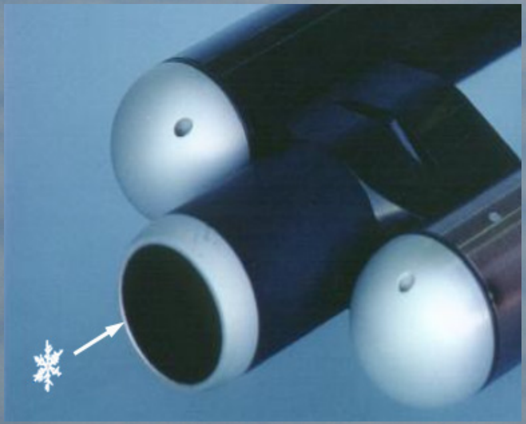
Shattering Effect: CAS vs CDP vs FSSP

Cloud and Aerosol Spectrometer

Shroud

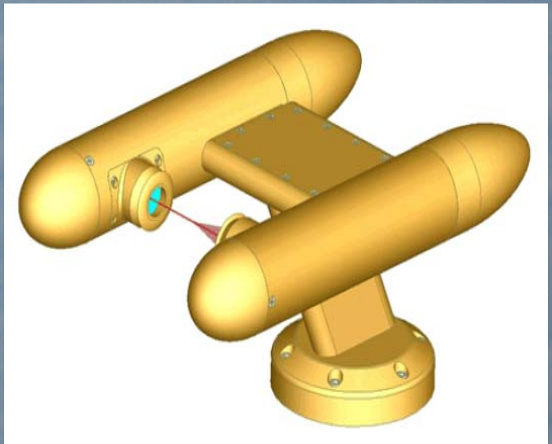
Inlet

Forward Scattering Spectrometer Probe



-Surfaces for shattering

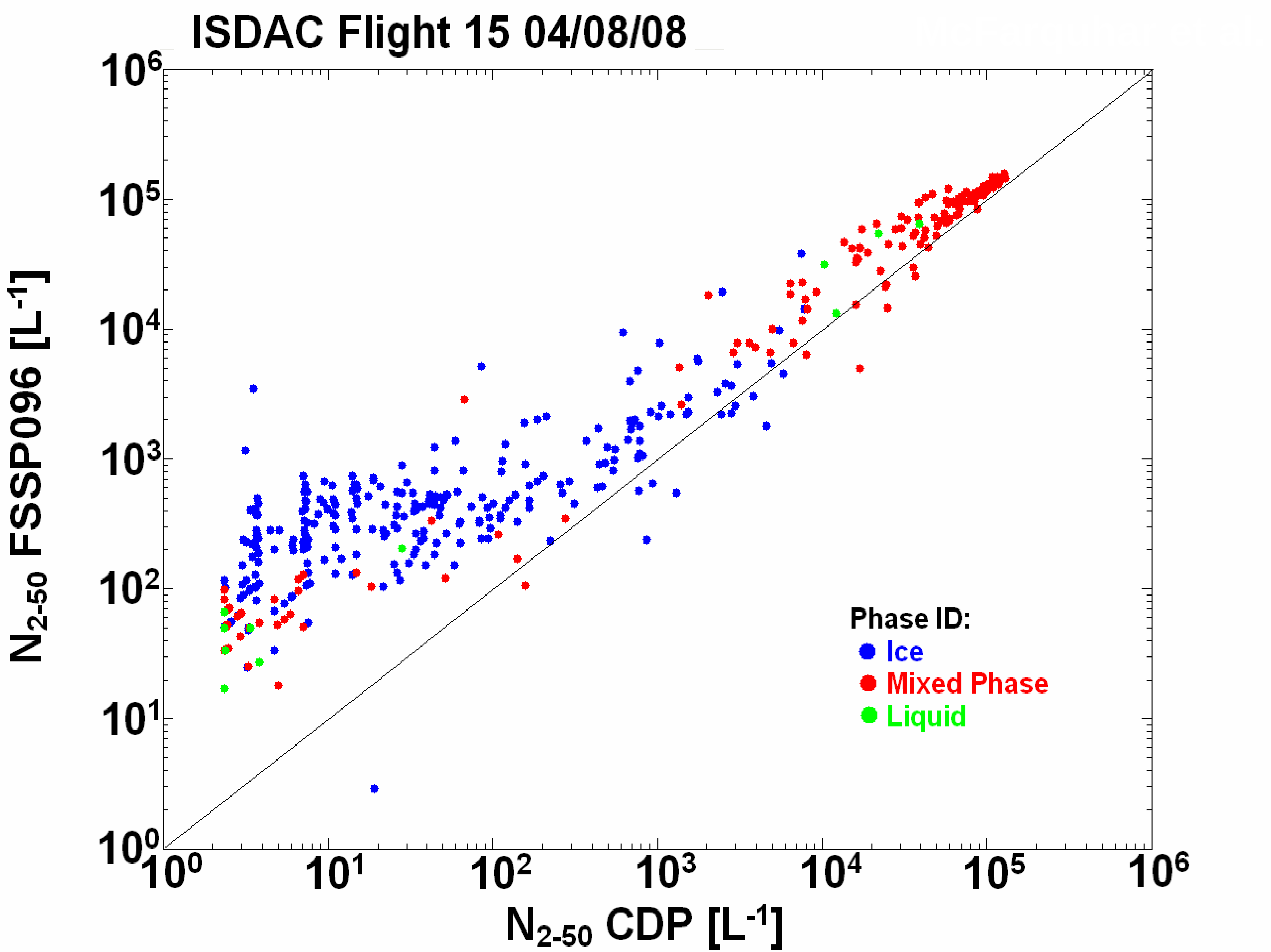
Cloud Droplet Probe



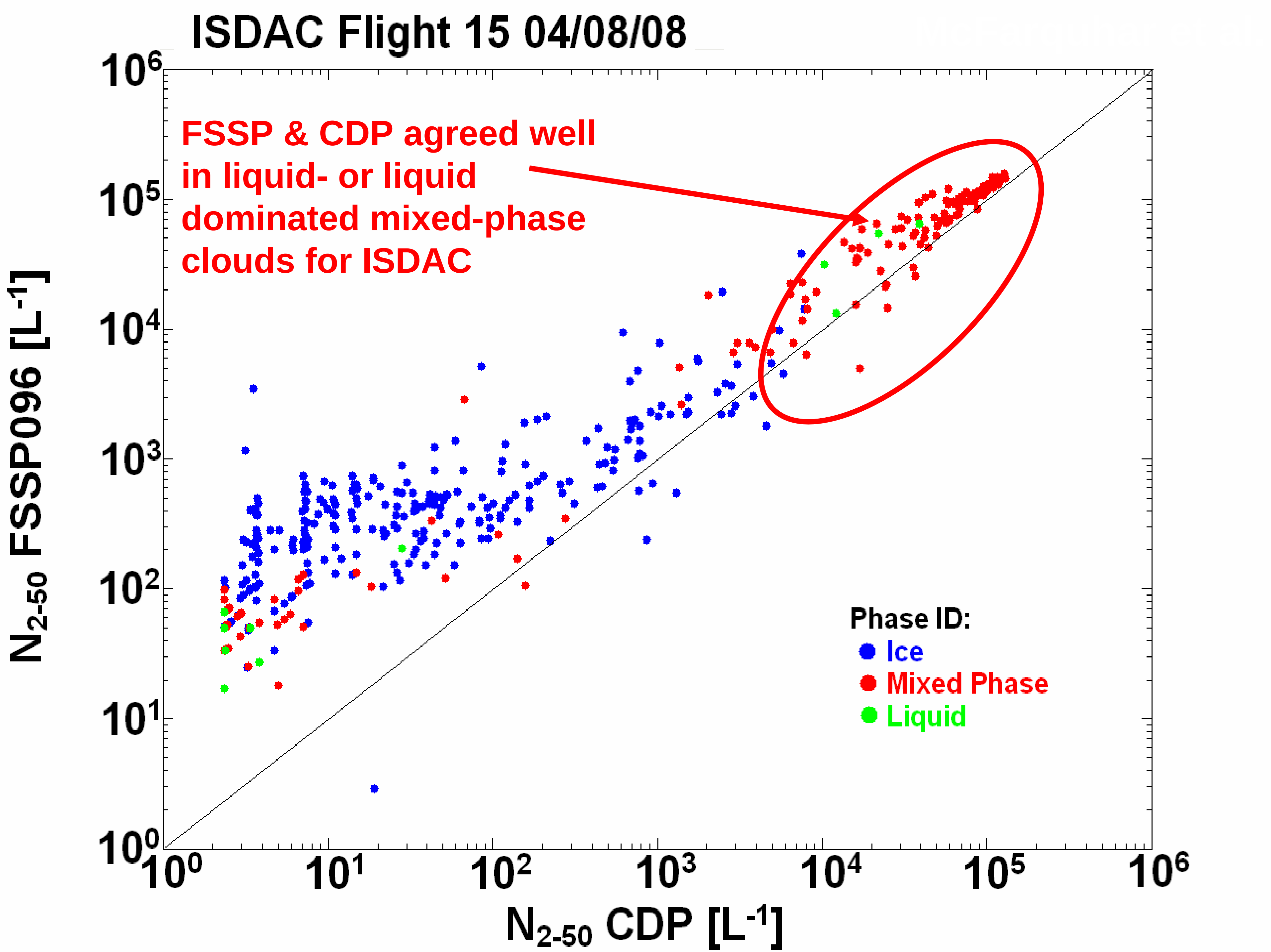
- No inlet or shroud

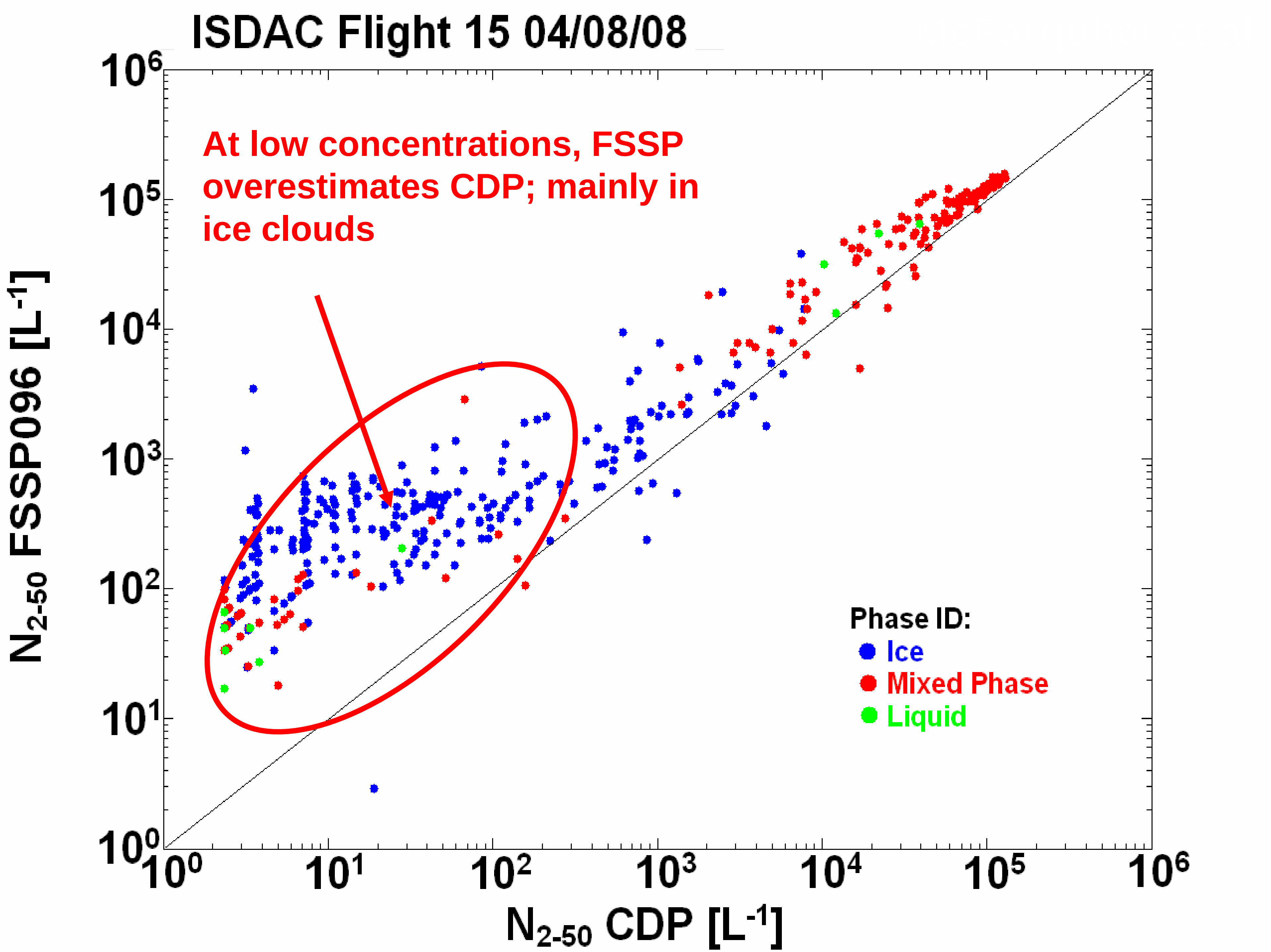
✓ The same working principle and look-up table

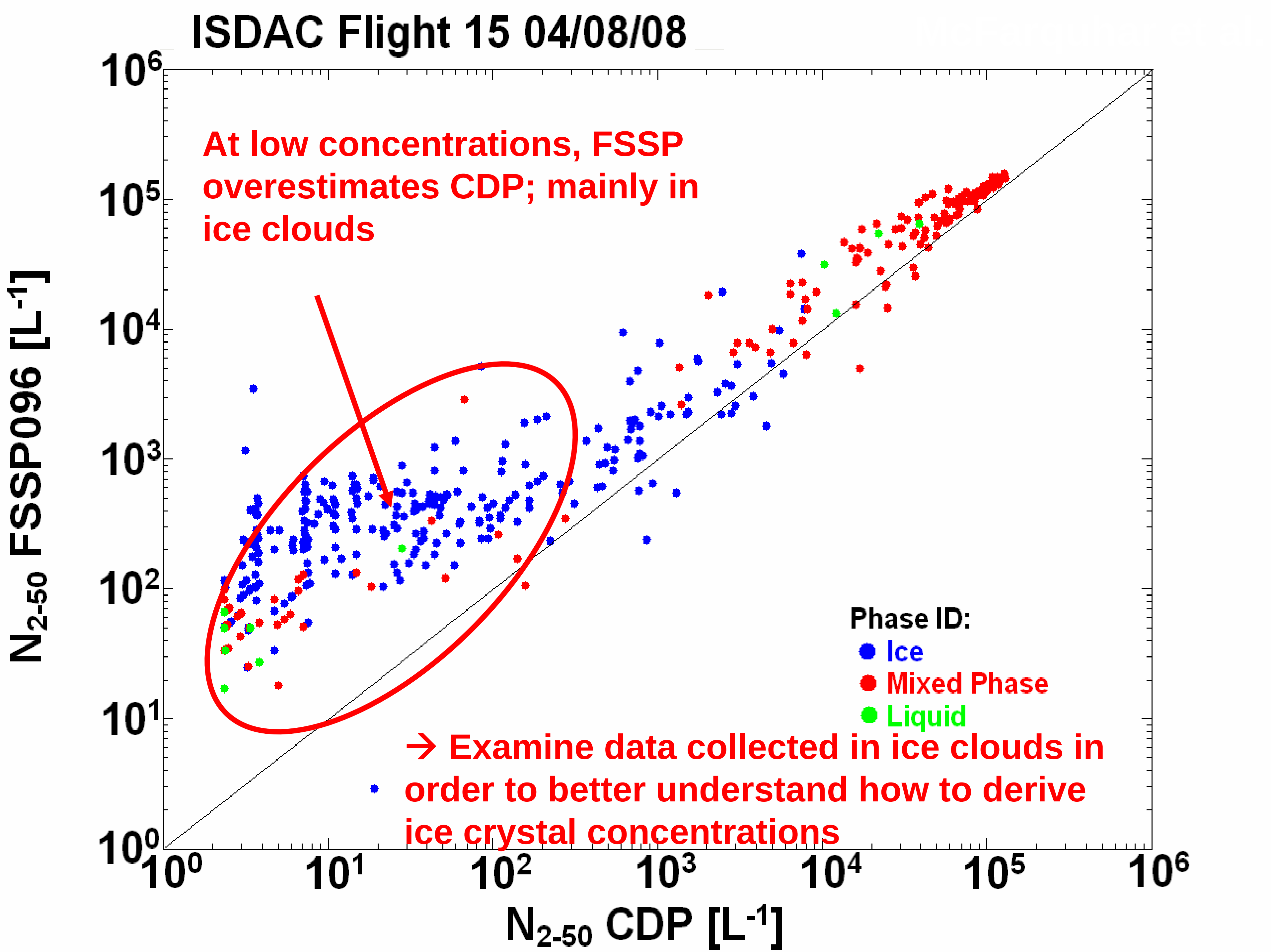
✓ Can we see shattering on FSSP or CAS?



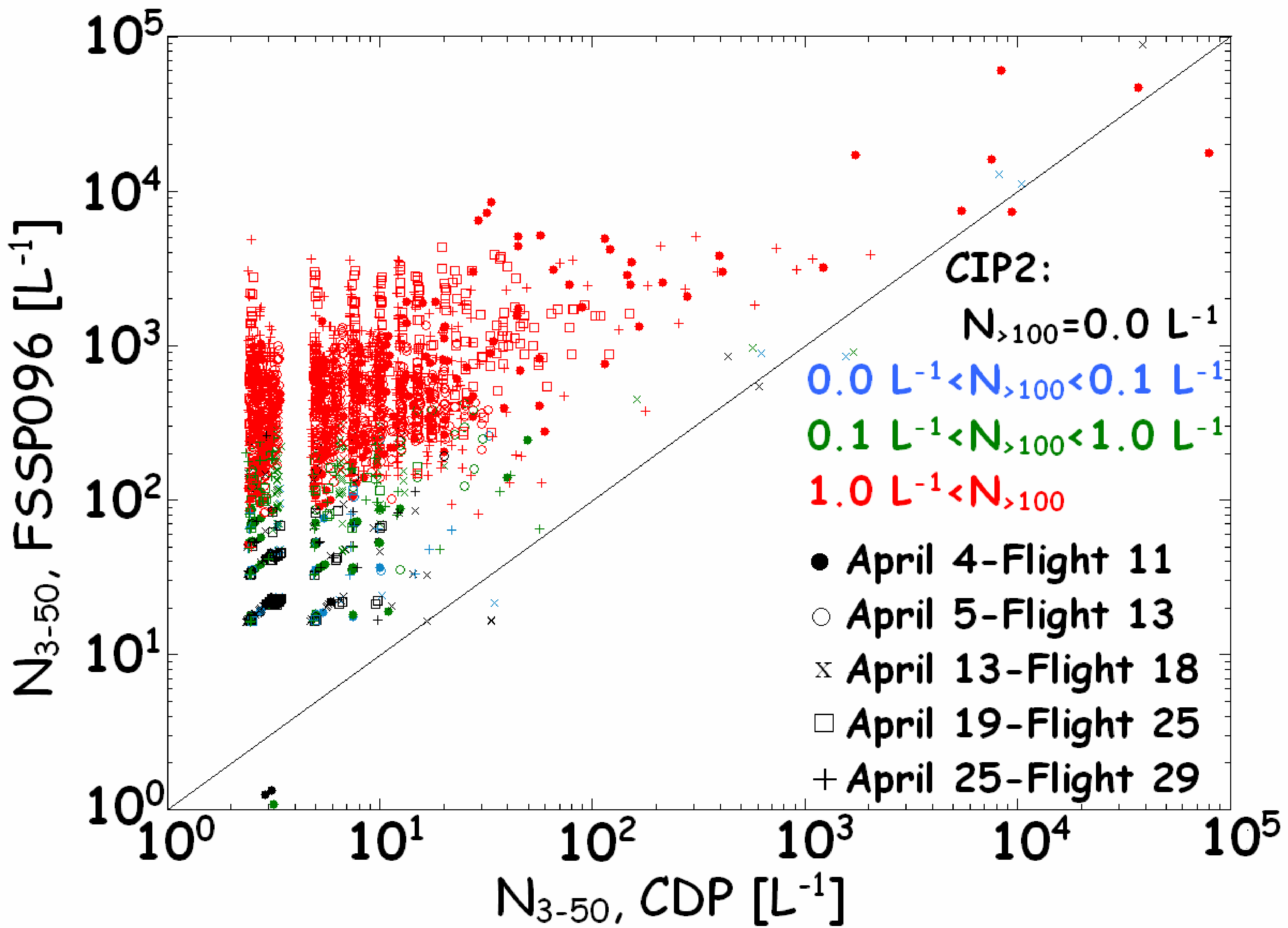
ISDAC Flight 15 04/08/08
N_{2-50} FSSP096 [L^{-1}]
N_{2-50} CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Phase ID:
Ice
Mixed Phase
Liquid


ISDAC Flight 15 04/08/08
FSSP & CDP agreed well
in liquid- or liquid
dominated mixed-phase
clouds for ISDAC
Phase ID:
Ice
Mixed Phase
Liquid
10^0
10^1
10^2
10^3
10^4
10^5
10^6
N_{2-50} CDP [L^{-1}]
N_{2-50} FSSP096 [L^{-1}]

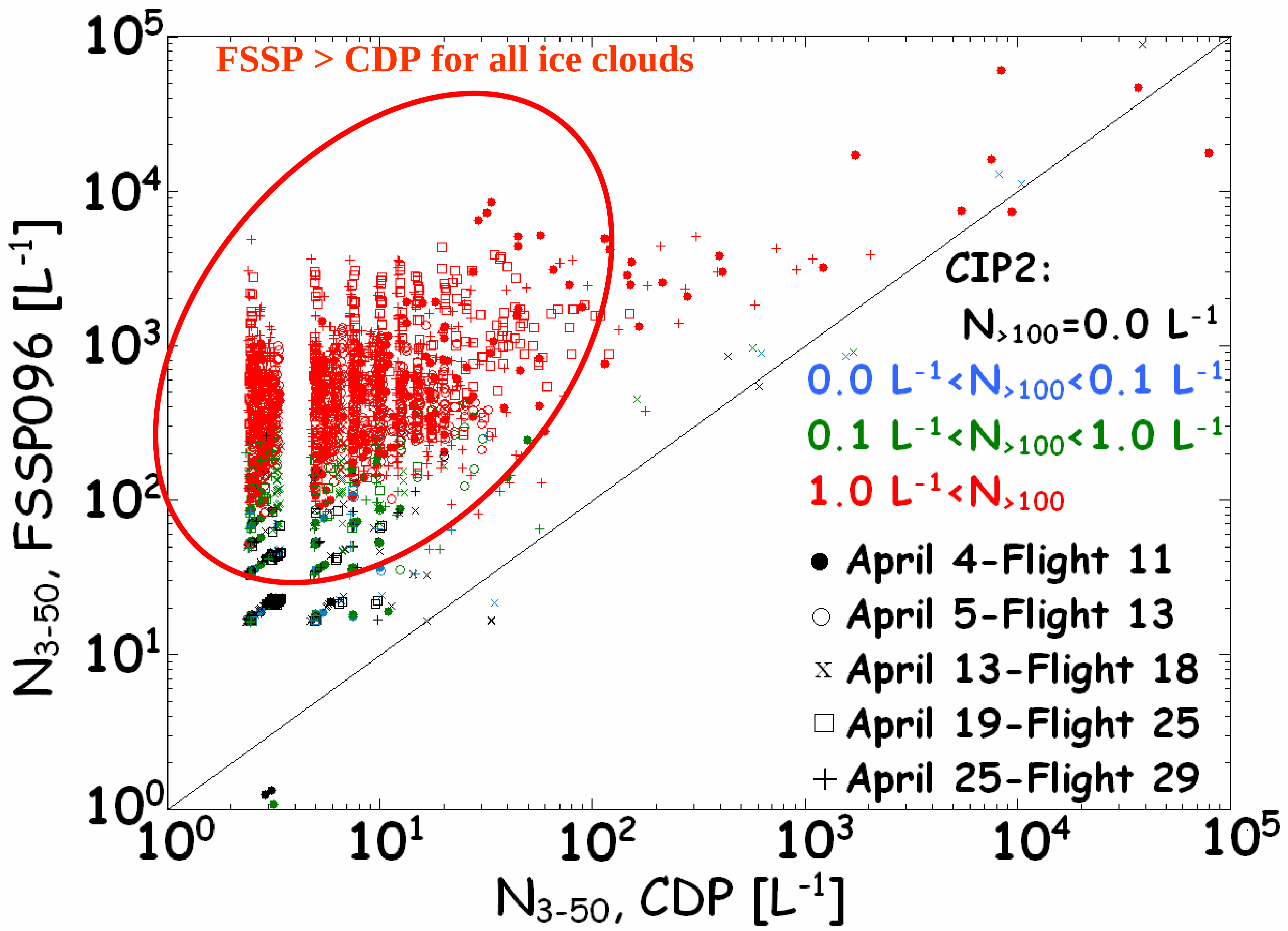

ISDAC Flight 15 04/08/08
At low concentrations, FSSP overestimates CDP; mainly in ice clouds
N_{2-50} FSSP096 [L^{-1}]
N_{2-50} CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Phase ID:
Ice
Mixed Phase
Liquid



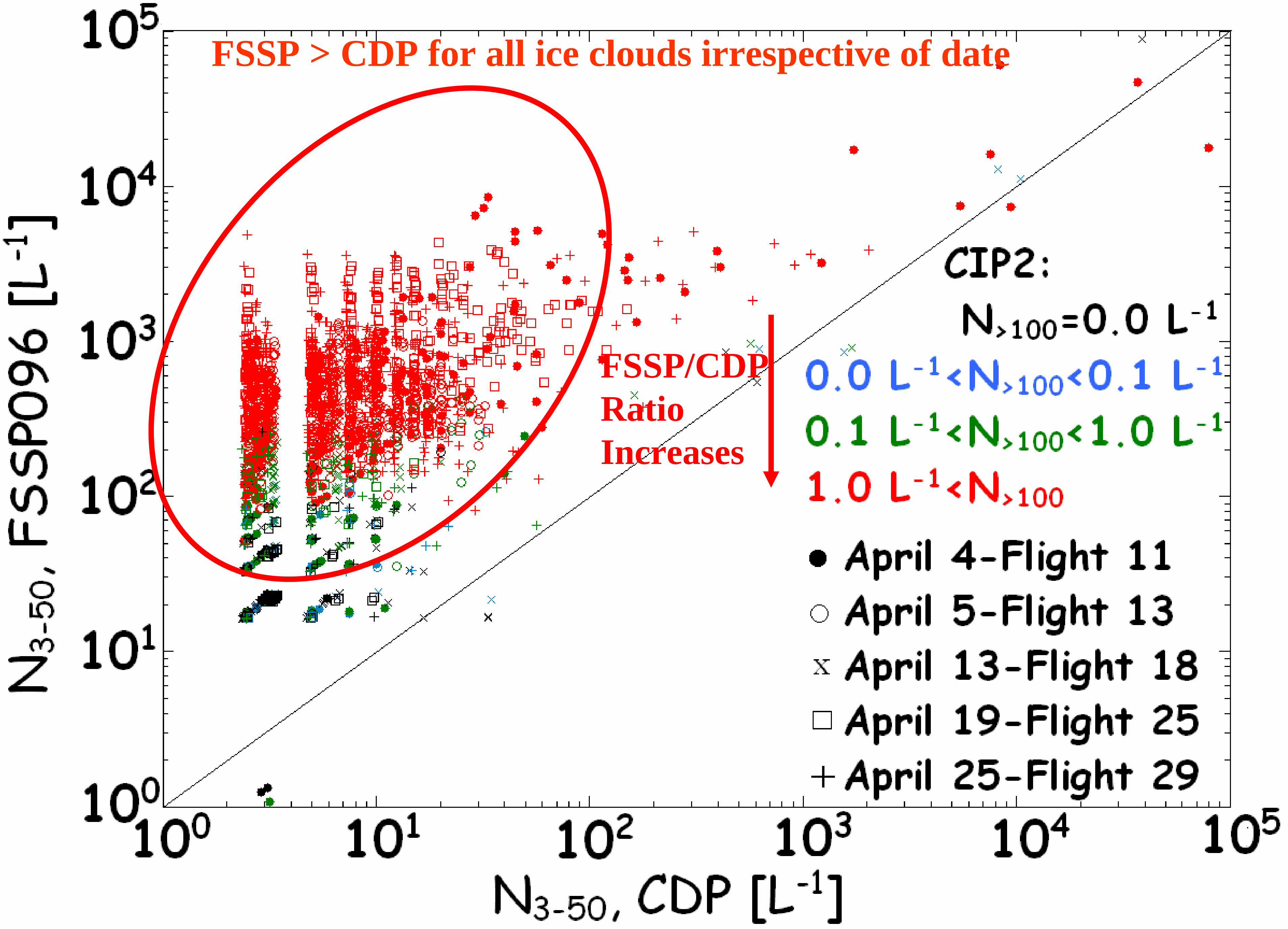
ISDAC Flight 15 04/08/08
At low concentrations, FSSP overestimates CDP; mainly in ice clouds
→ Examine data collected in ice clouds in order to better understand how to derive ice crystal concentrations
Phase ID:
Ice
Mixed Phase
Liquid
N_{2-50} FSSP096 [L^{-1}]
N_{2-50} CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
10^6



$N_{3\text{-}50}$, FSSP096 [L^{-1}]
$N_{3\text{-}50}$, CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
CIP2:
$N_{>100}$=0.0 L^{-1}
0.0 L^{-1}<$N_{>100}$<0.1 L^{-1}
0.1 L^{-1}<$N_{>100}$<1.0 L^{-1}
1.0 L^{-1}<$N_{>100}$
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29



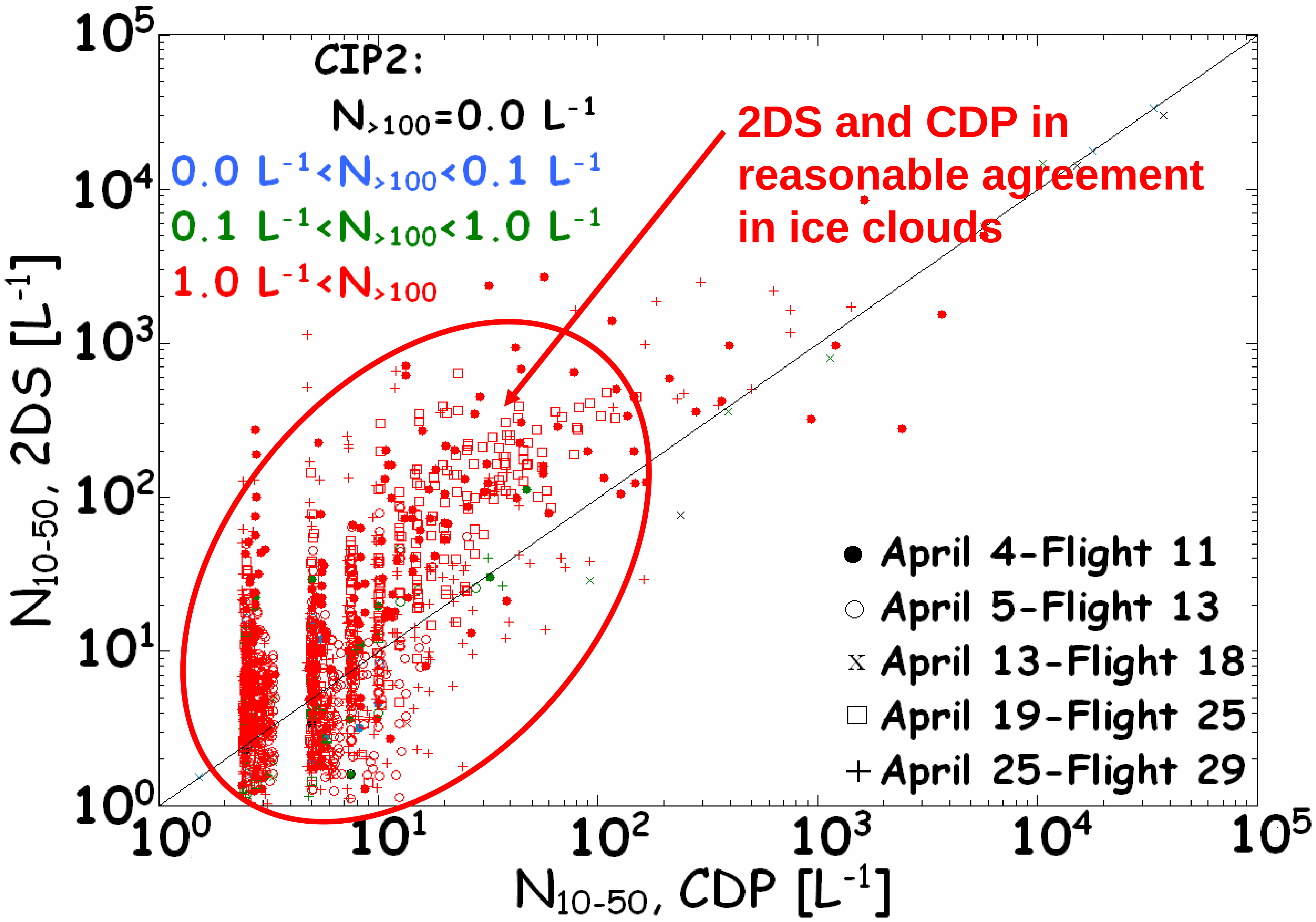
FSSP > CDP for all ice clouds
CIP2:
$N_{>100}$=0.0 L^{-1}
0.0 L^{-1}<$N_{>100}$<0.1 L^{-1}
0.1 L^{-1}<$N_{>100}$<1.0 L^{-1}
1.0 L^{-1}<$N_{>100}$
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N_{3-50}, FSSP096 [L^{-1}]
N_{3-50}, CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5



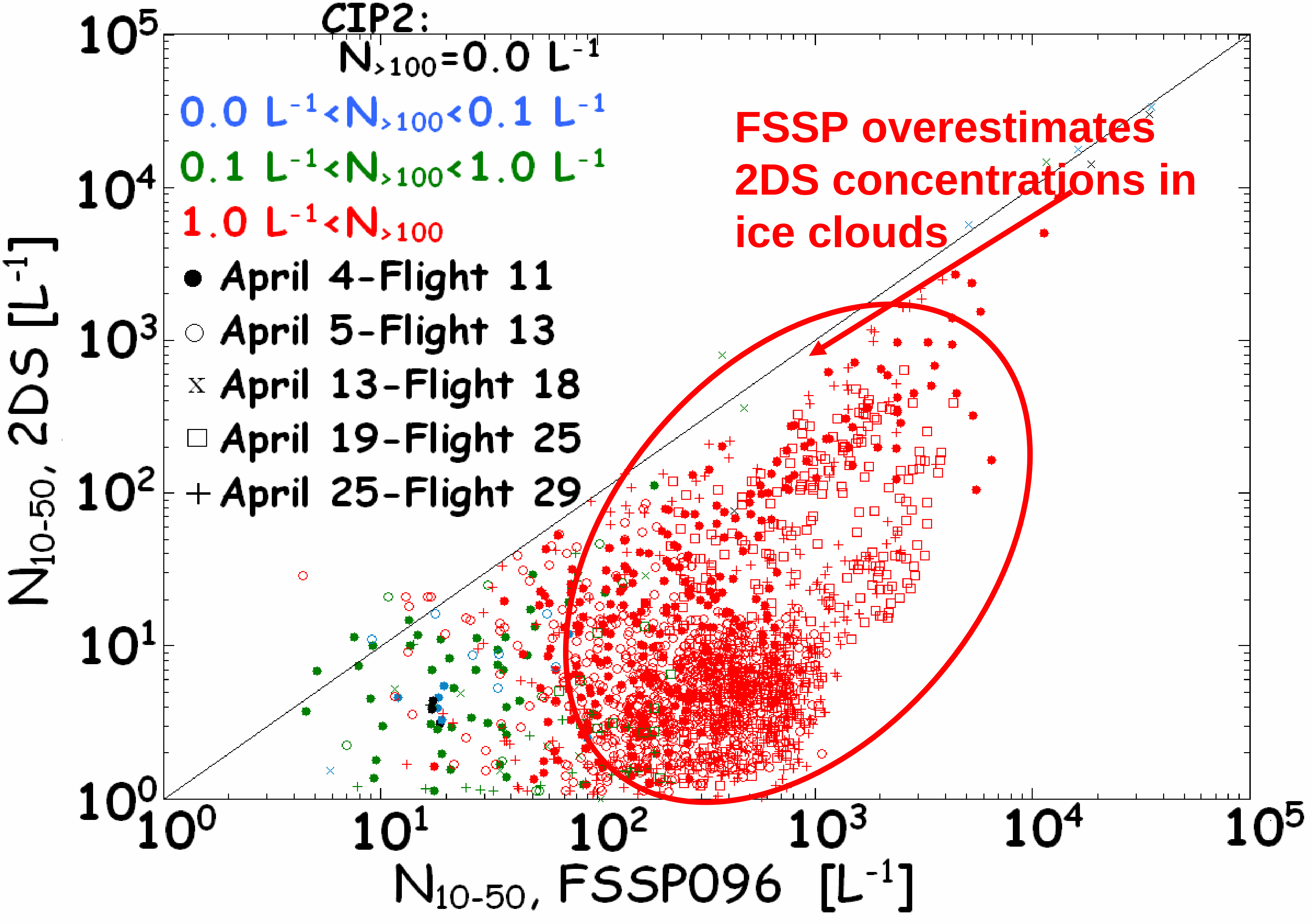
FSSP > CDP for all ice clouds irrespective of date
FSSP/CDP
Ratio
Increases
CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N3-50, FSSP096 [L-1]
N3-50, CDP [L-1]

SPEC Inc. 2-D Stereo Probe

- Two photodiode arrays capture 2-d images of ice particles with D > 10 µm
- Fills void between 50 < D < 125 µm from conventional OAPs
- May help quantify small ice concentrations by resolving shattering debate



CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
2DS and CDP in reasonable agreement in ice clouds
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N10-50, 2DS [L-1]
N10-50, CDP [L-1]



CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
FSSP overestimates 2DS concentrations in ice clouds
N10-50, 2DS [L-1]
N10-50, FSSP096 [L-1]
10^0
10^1
10^2
10^3
10^4
10^5

Enhancing Role of Students in Field Projects

- During RICO, a complete scientific mission including research flights of NCAR C-130, was planned & executed entirely by students (Rauber et al. 2007)
  - Novel, scientifically sound proposal written by students that had to fit within general goals of RICO
  - Operational plan & field responsibilities had to be identified by different students
  - Students came up with 3 goals for 8 hour mission of NCAR C-130

RICO Student Mission

- Three goals
  - Cloud processing of aerosols
  - Structure & dynamics of island tail clouds
  - Aerosol structure along a trajectory near the ground aerosol measurement tower at Antigua
- PIs were on flight for guidance, but left all decisions to students
- Students operated all but a couple of the instruments on C-130 for flight

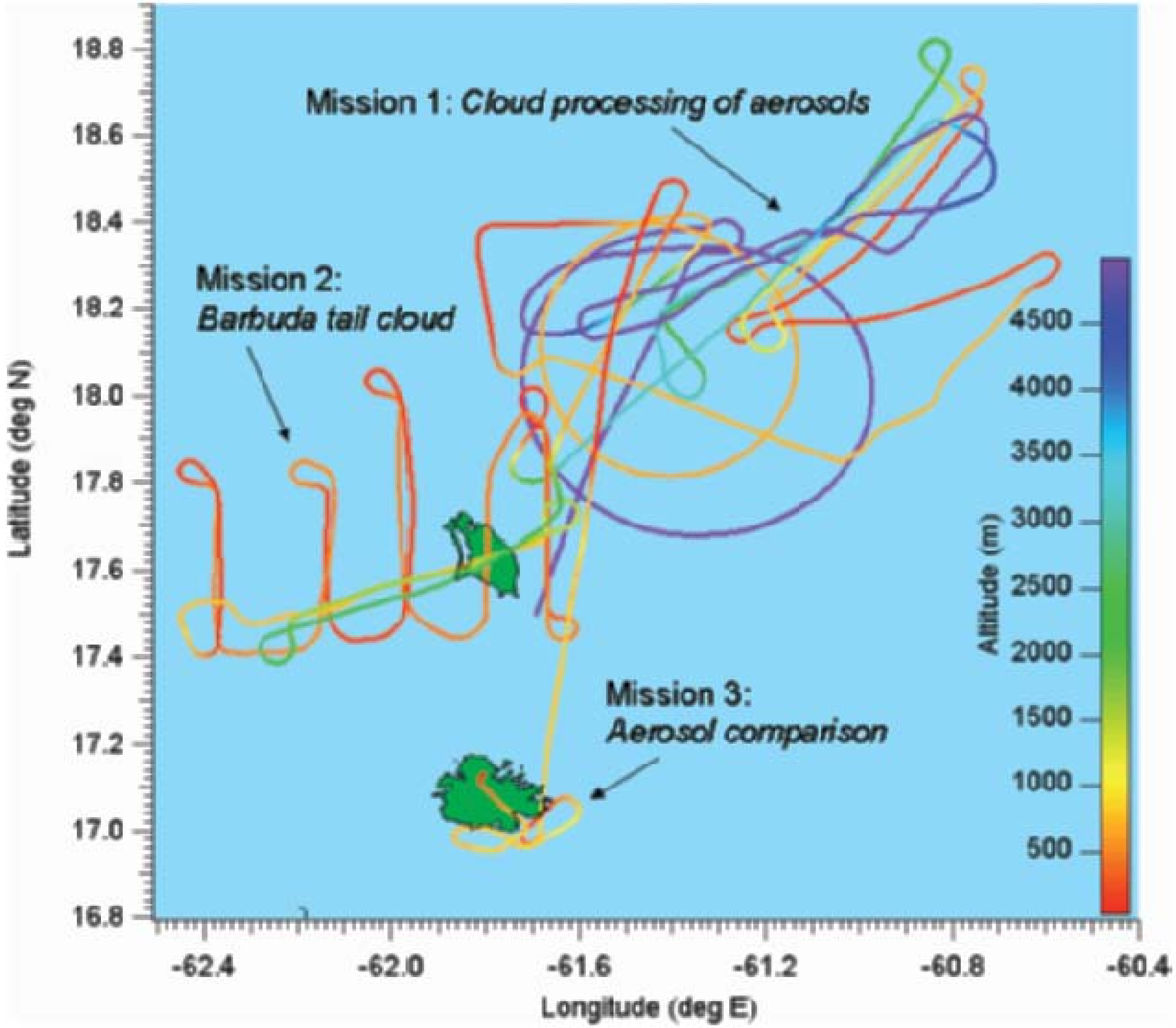


FIG. 1. Flight track of the NSF/NCAR C-130 during the student flight. The flight originated in Antigua (lower island) with operations northeast and west of Barbuda (upper island).

RICO

2004 2005

The importance of education in projects that use NSF facilities

2001 2008

In the Driver's Seat – RICO and Education

Robert M. Rauber, Bjorn Stevens, Jennifer Davison, Sabine Göke,*, Olga L. Mayol-Bracero, David Rogers,Paquita Zuidema, Harry T. Ochs III, Charles Knight, Jorgen Jensen, Sarah Bereznicki, Simona Bordoni, Humberto Caro-Gautier, Marilé Colón-Robles, Maylissa Deliz, Shaunna Donaher, Virendra Ghate, Ela Grzeszczak, Colleen Henry, Anne Marie Hertel, Ieng Jo, Michael Kruk, Jason Lowenstein, Judith Malley, Brian Medeiros, Yarilis Méndez-Lopez, Subhashree Mishra, Flavia Morales-García, Louise A. Nuijens, Dennis O'Donnell, Diana L. Ortiz-Montalvo, Kristen Rasmussen, Erin Riepe, Sarah Scalia, Efthymios Serpetzoglou, Haiwei Shen, Michael Siedsma, Jennifer Small, Eric Snodgrass, Panu Trivej, Jonathan Zawislak

The C-130 and King Air student missions
Education on the RVSJ
The Barbuda radar and sounding experience
Aerosol sampling on Antigua
Students – the RICO forecasting team
The RICO seminar series
Outreach to the islands

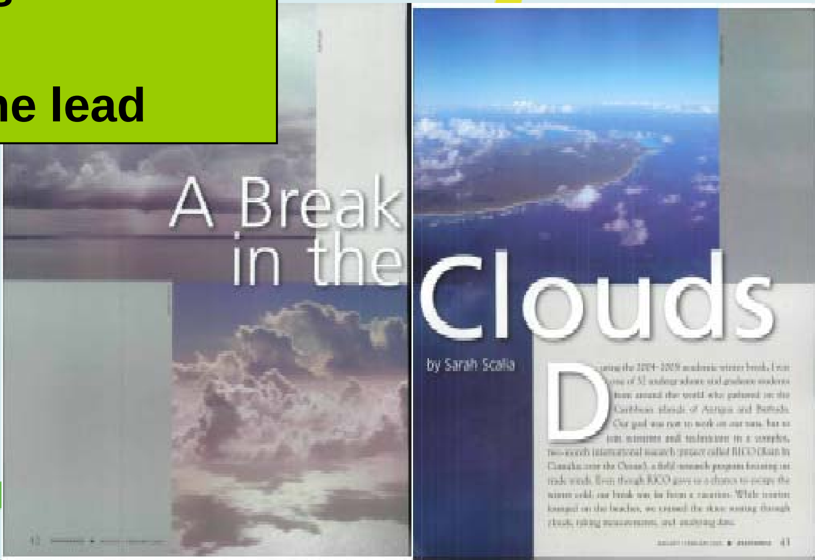
Publication: Students take the lead

2002

2001

Op jacht naar cumulus tijdens RICO

Louise Nuijens (Wageningen Universiteit)



Community Support

- Important to engage members of community about the work that we are doing (particularly K-12 students)
- E.g., during recent ISDAC experiment out of Fairbanks, engaged in 2 such activities
  - Science Potpourri, whereby K-8 students sprinkled drops in flour, measuring sizes of raindrops
  - GLOBE pole-to-pole video conference

Data Availability

- For students not able to participate in projects, there are opportunities to analyze project data
  - data products in open archives 6 to 12 months after project completion (e.g., DOE ARM, NASA, NSF archives)
  - Many PIs do not have time to analyze their own data, so many interesting discoveries await!
  - E.g., from our recent M-PACE experiment, 12 co-authored papers by PI with students/postdocs from varying universities have been written

Upcoming Opportunities: PLOWS

- PLOWS will improve understanding of precipitation structures in NW & warm frontal quadrants of continental extra-tropical cyclones.
  - NCAR C-130 & sounding system & UAH MIPS & X-band radar to be used
- Strong educational component to PLOWS
  - MIPS will be brought to 8 universities in mid-west
  - C-130 will land at 3 central locations
  - Datasets to be used in class projects at these universities
  - Undergrad & grad students will be involved in mission planning, data collection, quick looks & post-project analysis
  - REU applications being accepted from undergraduate students


PLOWS 2008-2009
Field Catalog


National Science Foundation
Where Discoveries Begin

Summary

- Observational campaigns remain at forefront of atmospheric science
  - enhance understanding of atmospheric processes
  - evaluate model performance
  - provide data for parameterization development

- There has been & will continue to be ample opportunities for student involvement
  - assistance in operating instruments during campaign
  - analysis/quality control of data during campaign
  - science investigations after campaign
  - Making meaningful contributions to planning and execution of science missions

How many probes needed?

During recent ISDAC experiment in Alaska, National Research Council of Canada (NRC) Convair equipped by Environment Canada, NRC, universities & companies with 41 instruments to measure aerosol and cloud particles from 1 nm to > 10 mm in size